HYPERVIB2

A MODEL-BASED
COMPUTER PROGRAM
TO EVALUATE THE PENETRATION SPEED
OF VIBRATORY DRIVEN SHEET PILES

BBRI

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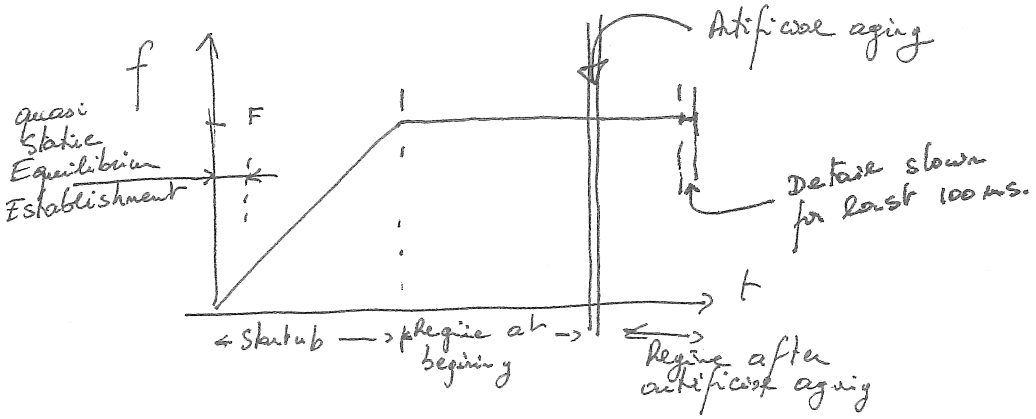
Irvine, February 1994

CONTENTS

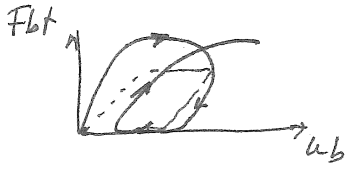
GENERAL APPROACH

- Implements model and constitutive behaviour discussed in report "HyperVib II a" of September 1993, except for following amplifications:

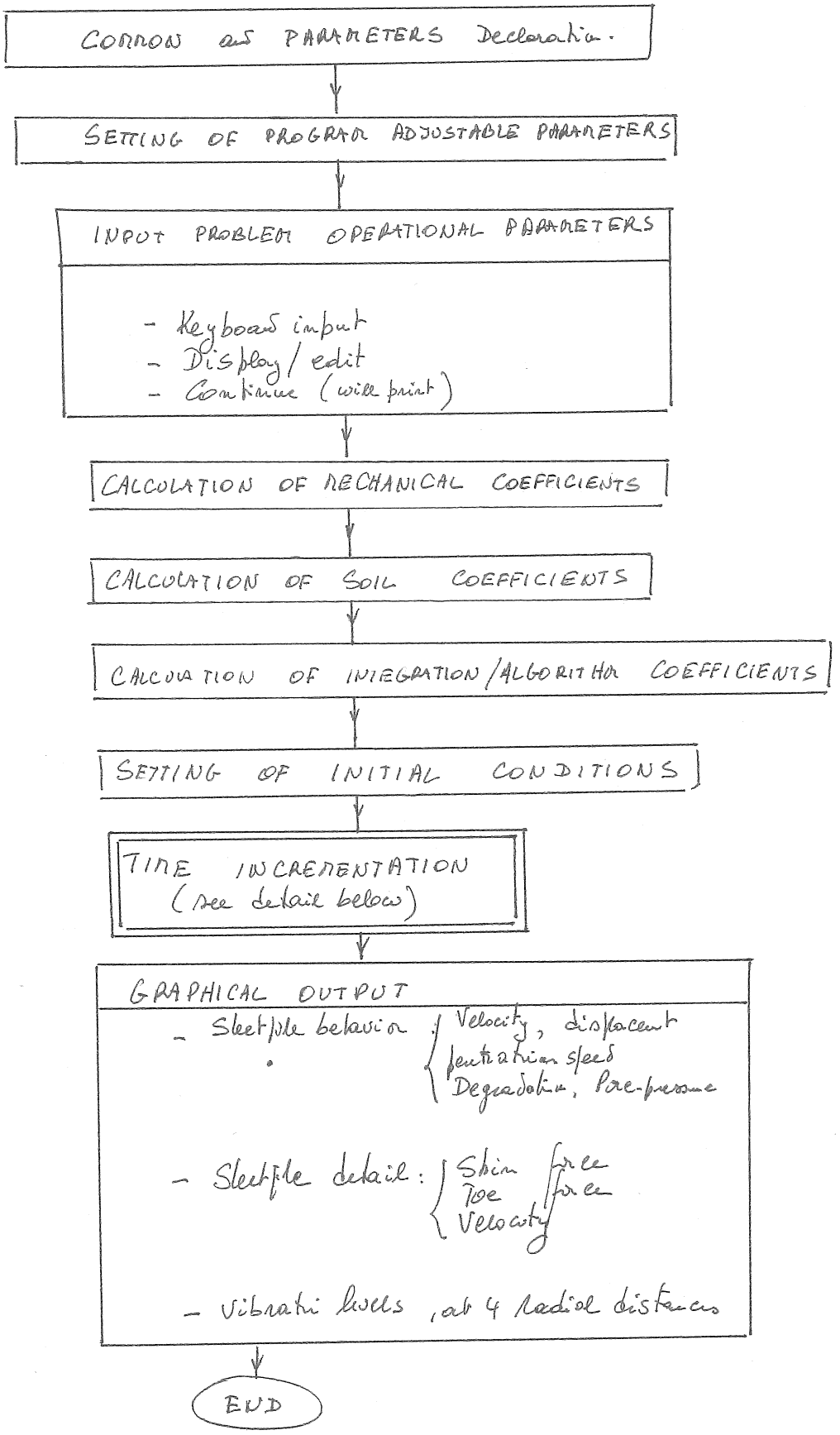
- Regime of vibration can be fully simulated by assuming
  - a start-up phase
  - a regime upon start of potential levitation
  - a regime after artificial aging (introduced to see effect of degradation due to many cycles without having to calculate them)

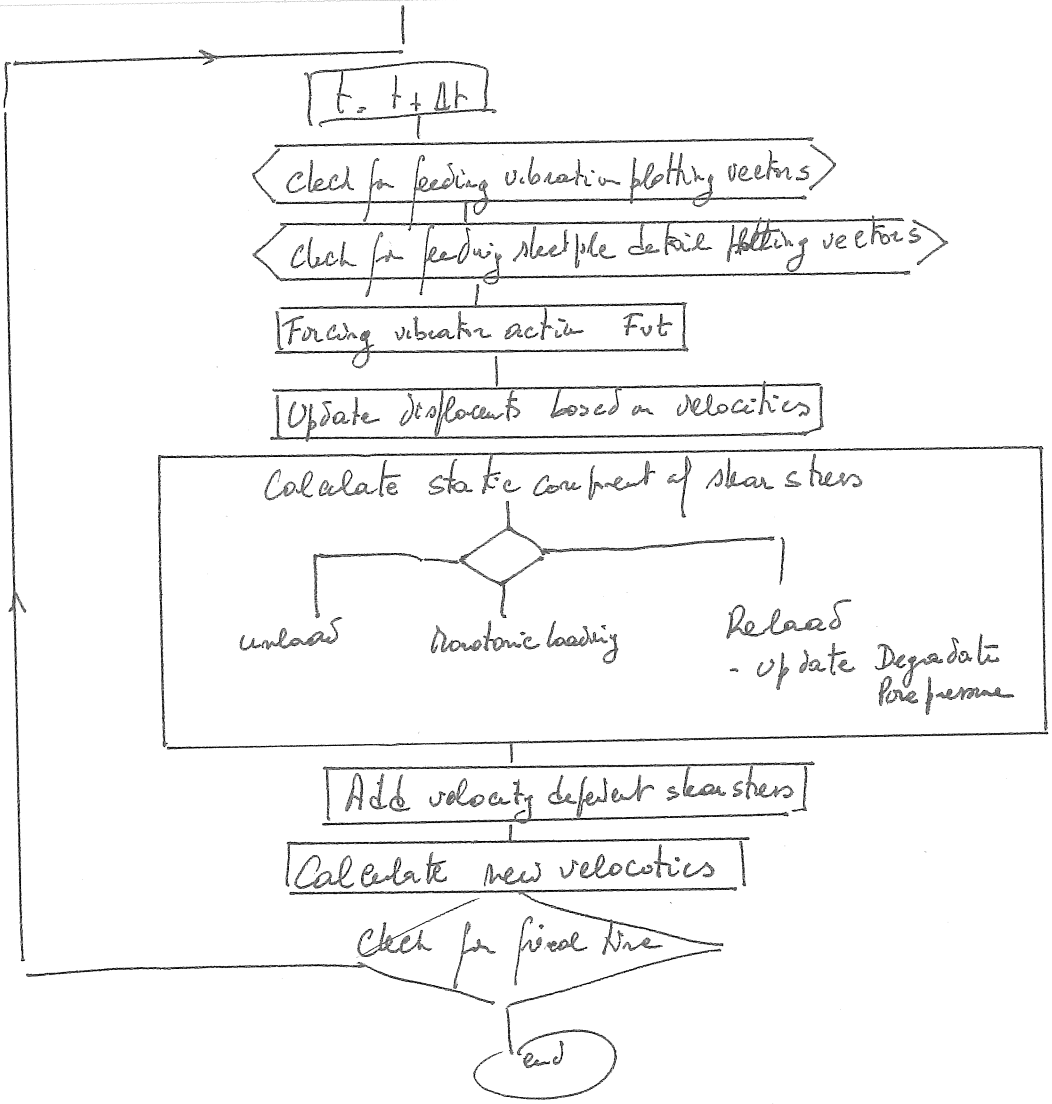


- End bearing (simple visco-elasto-plastic model) was added at toe.

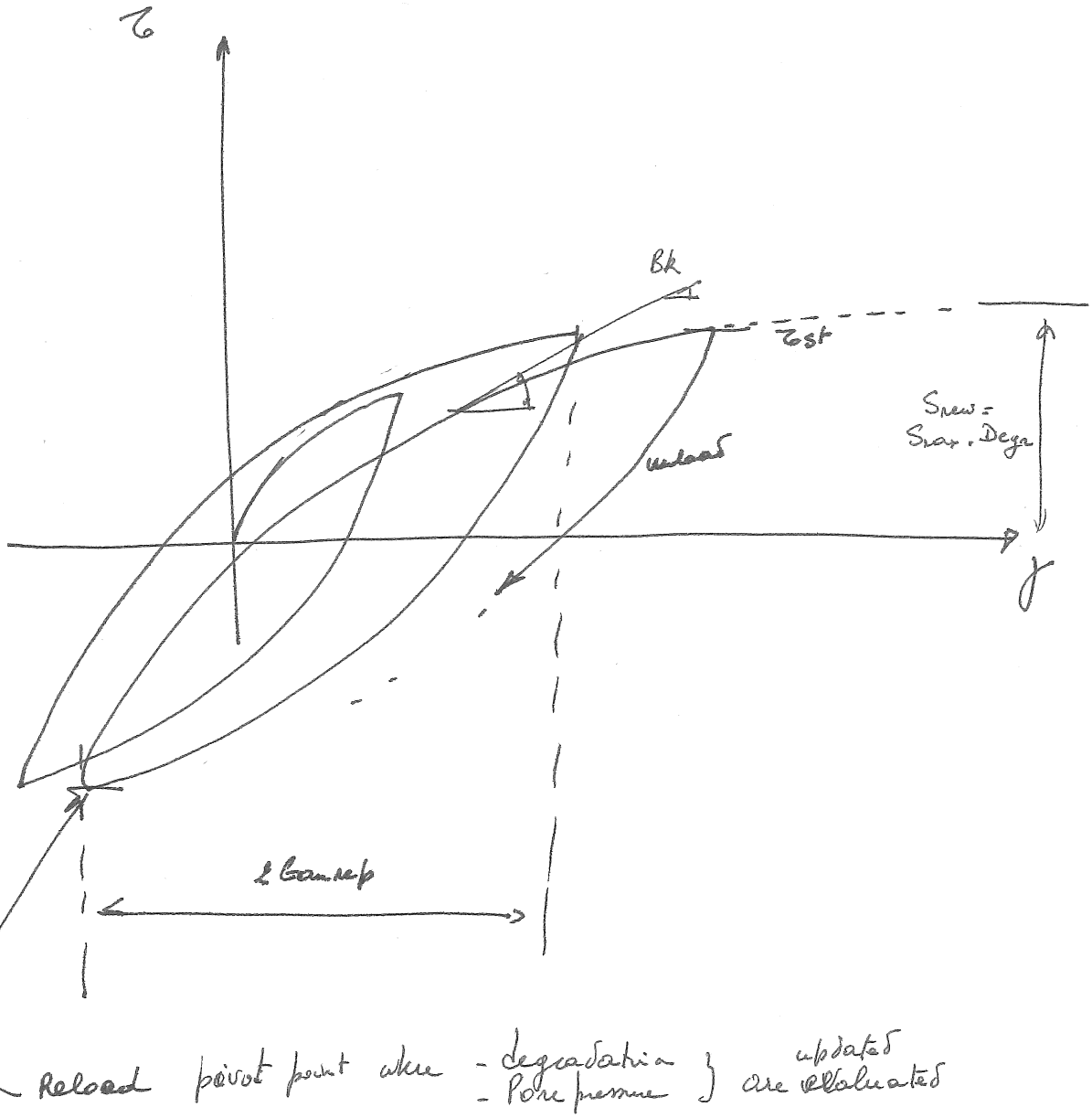


- Degradation is assumed to take place only below water table
- Spring at outer boundary was introduced to provide static equilibrium (Time required for establishment is $\pm 2(R_{max} - R_b)/V_s$) as a result of outer field behavior at appropriate adimensional frequency - (Bessel functi simplified to a constant - See my Thesis p 434)


COMMON and PARAMETERS Declaration.
SETTING OF PROGRAM ADJUSTABLE PARAMETERS
INPUT PROBLEM OPERATIONAL PARAMETERS
- Keyboard input
- Display / edit
- Continue (with print)
CALCULATION OF MECHANICAL COEFFICIENTS
CALCULATION OF SOIL COEFFICIENTS
CALCULATION OF INTEGRATION / ALGORITHM COEFFICIENTS
SETTING OF INITIAL CONDITIONS
TIME INCREMENTATION
(see detail below)
GRAPHICAL OUTPUT
- Sheetpile behavior: Velocity, displacement; penetration speed; Degradation, Pore-pressure
- Sheetpile detail: Shim force; Toe force; Velocity
- Vibrator levels, at 4 radial distances
END


t, t + Δt
Check for reading vibration plotting vectors
Check for reading steel pile detail plotting vectors
Forcing vibration action Fvt
Update displacements based on velocities
Calculate static component of shear stress
unload
Monotonic loading
Reload
- update Degradation
Pore pressure
Add velocity dependent shear stress
Calculate new velocities
Check for final time
end

CONSTITUTIVE RELATIONSHIP



Reload pivot point when - degradation - Pore pressure } are updated evaluated

SUMMARY OF SOIL VARIABLES

RUN INPUT (= "variable")

Zd = Pile penetration
Zw = Depth to water table

Qcf = Cone resistance } Shaft friction
Frf = friction ratio }

Qcb = Cone resistance } Toe resistance
Frb = friction ratio }

PROGRAM Adjustable (= "parameter")

Alph = ring thickness ratio	.03	-
Rho = Volumic mass	1.8	t/m³
Ka = Gmax/Qcf (shaft)	15	-
Kab = Gmax/Qcb (base)	15	-
Cbe = base damping ratio	1	-
Nvec = Velocity dependent exponent	0.2	-
Nu = Poisson's ratio	0.4	-

MECHANICAL VARIABLES

Me = excentric moment
F = frequency
Mv = Vibrating mass of vibrator
Ms = Stationary mass of vibrator
Aacier = Section of steel pile
Perim = Perimeter of steel pile
Zlong = Length of steel pile

Gacs = steel volumic mass	7.85	t/m³
G = gravity	9.81	m·s⁻²
Cwav = wave velocity	5,200	m·s⁻¹

SUMMARY OF MODEL VARIABLES

Run INPUT (= "Variables")

Nr : Number of radial elements

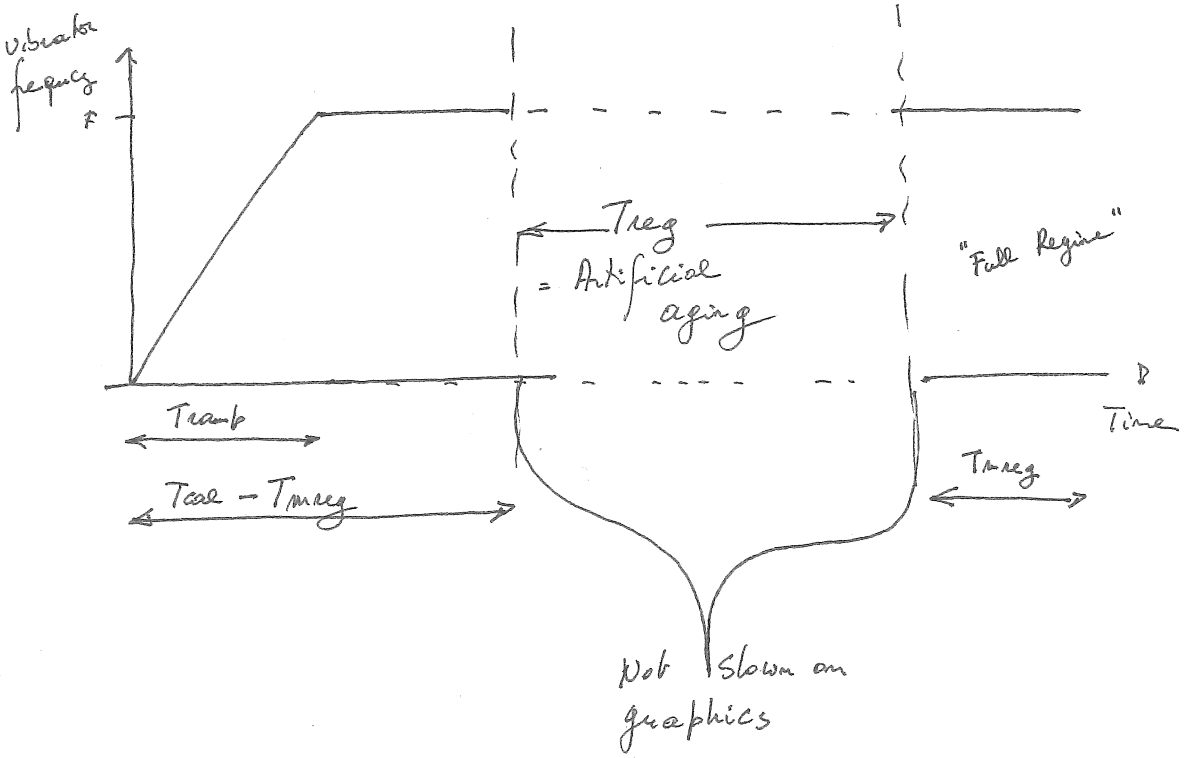
PROGRAM Adjustable (= "parameter") (typical value)

Tramp (0.5 sec) : Time required to ~~decrease~~ start vibration (i.e to increase frequency for 0 to F)

Tcal (2 sec.) Total calculation time

Tmreg (1 sec) Last time segment of Tcal over which "full regime" is simulated

Treg (60 sec) Aging time used to simulate "full regime"



Rmax (2m) Radial extent of model

Ndit (1) Time increment reduction.

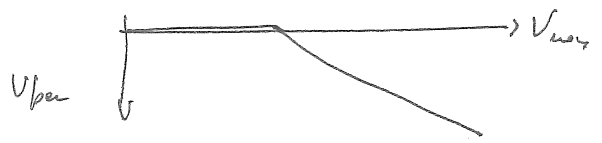
Nglu (0) Mass of soil attached to sheet pile

Radial extent of model can be increased to model vibrations at larger distances. However because soil at beyond that distance is generally within elastic range, it is more effective to use attenuation relationship to relative to that reference radius.

To keep same integration procedure, Nr should be increased as Rmax, which means that calculation time would increase with square of maximum radius.

USING TIPS

- In H-P Instrument basic, open "HYPERVIB2.IBW"
- Click Run
- Input variable for 1st run, display to edit (in Help window, type "name of variable = Value" ; eg: "Frf = 1.5")
- Enter, Enter of Display to edit subsequent runs (when running parametric analyses)
- Follow procedure indicated to print graphs at the end of calculation, ~~Press "cont~~ Click "CONT" to show next graph
- Click Run for next run.
- Program is not "idiot-proof", please record set of parameters leading to problem, for potential upgrade of program.
- Run parametric analyses by varying Frf (most significant variable) and try to establish parameters governing the relationship between Vmax & Vpen, assumed under Hypervib 1.



Try first with $2w > 2d$, for no degradation

SAMPLE PROBLEM

Use data provided in BBRI Report for Hingene.

- PIC 50 HZ – See attached print out of input.
- qcf = average of qc over depth
  FR = ——— FR ——— ,
  OR BETTER: evaluate fs over depth, / qc ——— } calculate equivalent FR = fs/qc
- See annotated plots
  - Sheet pile behavior over Tcal (2sec.)
  - Detail of sheet pile behavior 2 end 100 ms
  - Vibration at 4 various distances –
- During program run, & screen provide a dot = "." per time increment of Tcal/Npl (= 2/500 = 4ms) and on "Time = ———" per cycle – (Note that at early stage, many cycles are reflecting the system moving toward quasi equilibrium).
- Make sure that regime gets established by more or less uniform number of ~~point~~ dots before "Time = —" statement.
  A bad example is provided that shows erratic vibration pattern evidenced by limited cases of degradation and liquefaction.
  This was caused by a very high value of skin friction (180 kPa); problem (if need to be addressed...) would require increasing Ncrit (and calculate with a shorter time increment) or Nr.

Great insight can be gained by varying water table (if $z_w > z_L$, no degradation takes place)

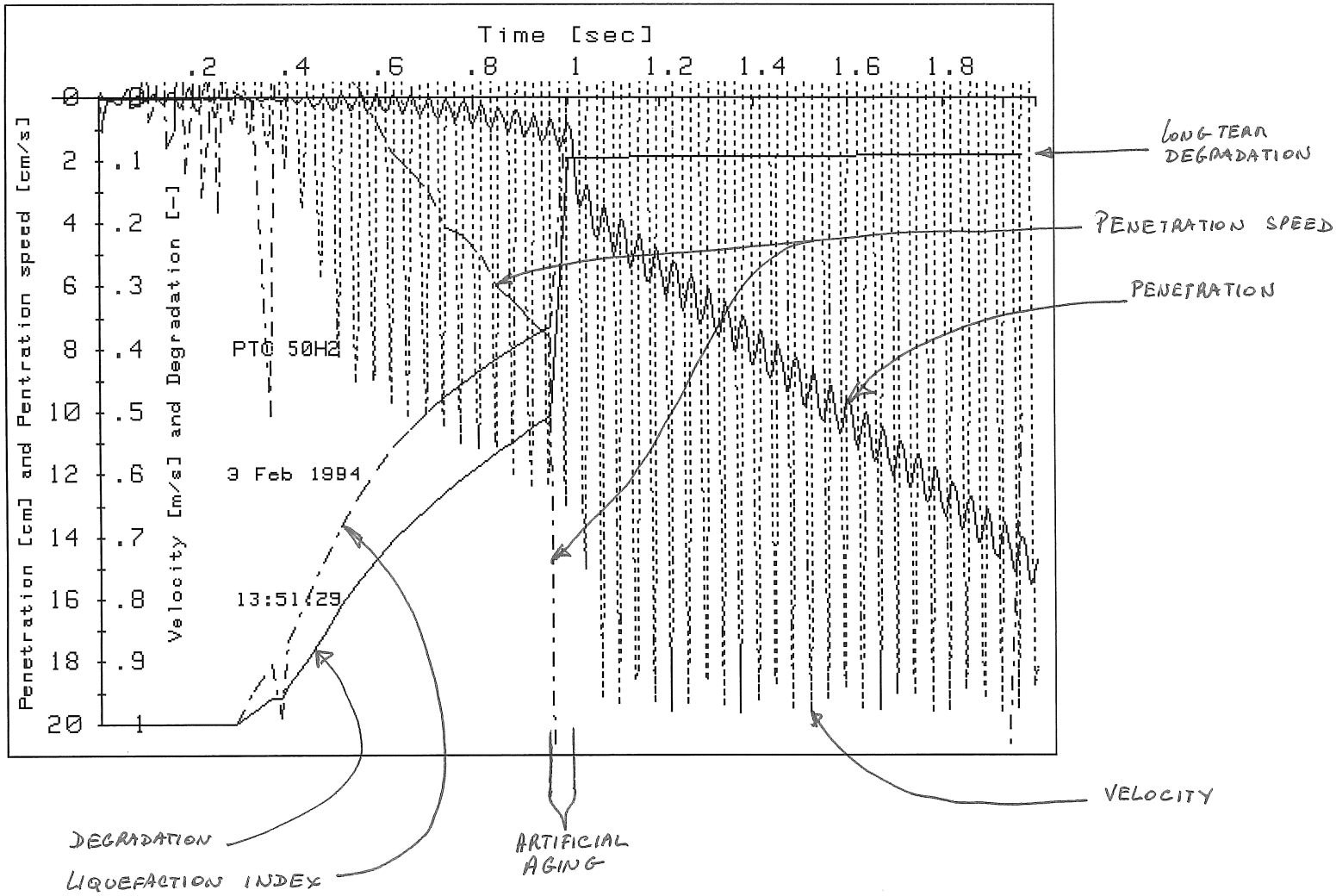
It can be noted that vibrate levels can decrease after degradation/liquefaction takes place, explaining apparent resonance at start-up and turn off of the vibrator.

Note that vibrations are calculated under the assumption that the crane operator applies no restraint to the vibrator. Vibration levels should decrease under continuous vibrations produced by a vibrator held in place. The restraint coefficient can be modified from 1.0 to a lower number to artificially reduced shaking weight.

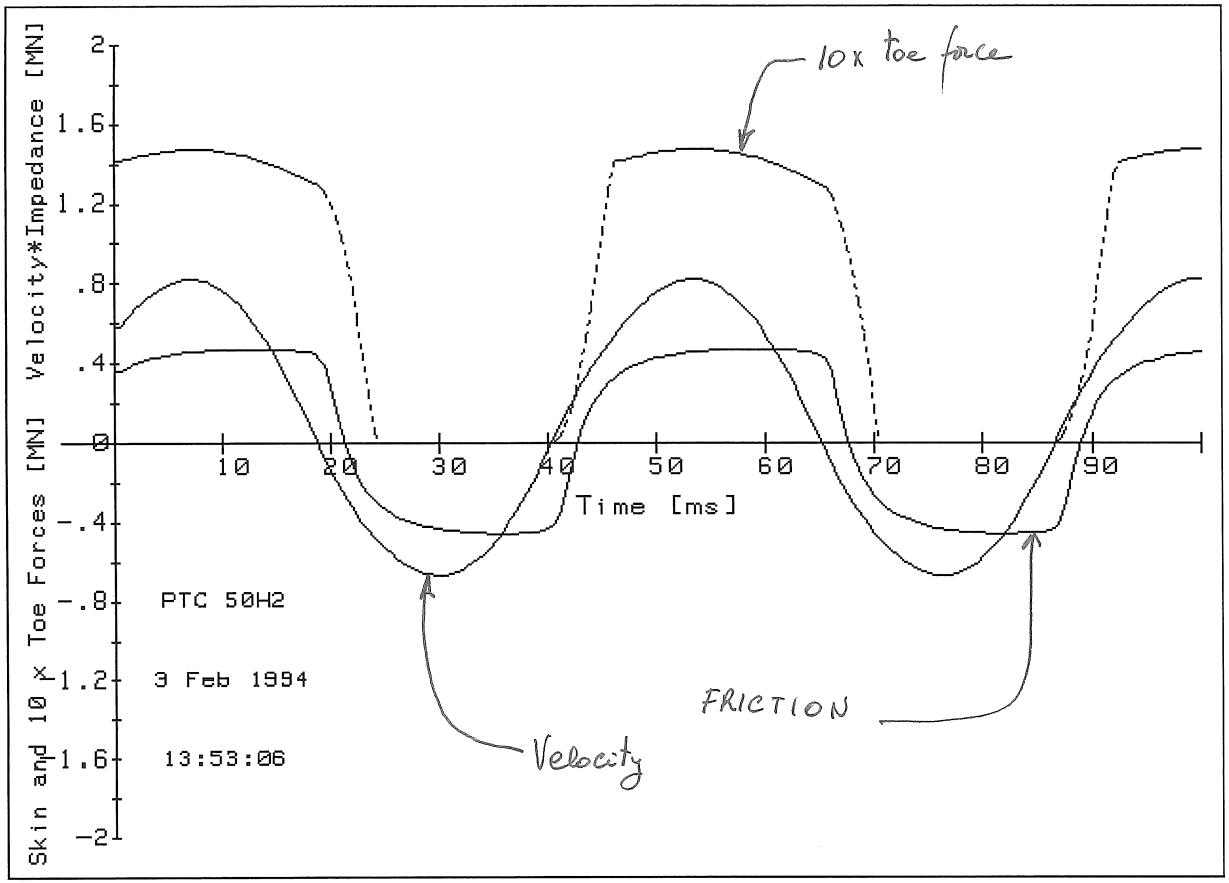
For $R_{max} = 2$ m, $T_{col} = 2$ sec and $N_2 = 20$, my 486 DX2 (50 MHz) takes approximately 20 min. To explore time reductions, calibrate problems run with smaller R_{max} and N_2 to full time problems.

Adjustment with measurements should be able to reproduce both sheet pile and ground vibration level - (!)

```
version  'HYPERVIB2'                                        3 Feb 1994      13:28:33
 0         2         1         2         0         15         15         1
****************************************
         BBRI Sample Problem
    Hingene March 1993
****************************************


PTC 50H2

Eccentric Moment =    50        kg.m
Frequency =           27        Hz
Vibrating Mass of Vibrator =    6700      kg
Stationary mass of Vibrator =   3500      kg

Section of Sheet pile =          167       cm2
Perimeter of Sheet pile =        2.88      m
Length of Sheet pile =           11.7      m

Pile penetration =    10        m
Depth to water table =           2         m
Number of radial increments =    20
FRICTION: Average cone resistance =       6000      kPa
                  Friction Ratio  =       2         %
TOE :             Cone resistance =       10000     kPa
                  Friction Ratio  =       2         %
delta=      .0002
ntmax=     10000

ESTIMATED RESULTS


Estimated driving speed at     10 m. is 2.88 m/min at early regime
Estimated driving speed at     10 m. is 14.51 m/min at full regime
```

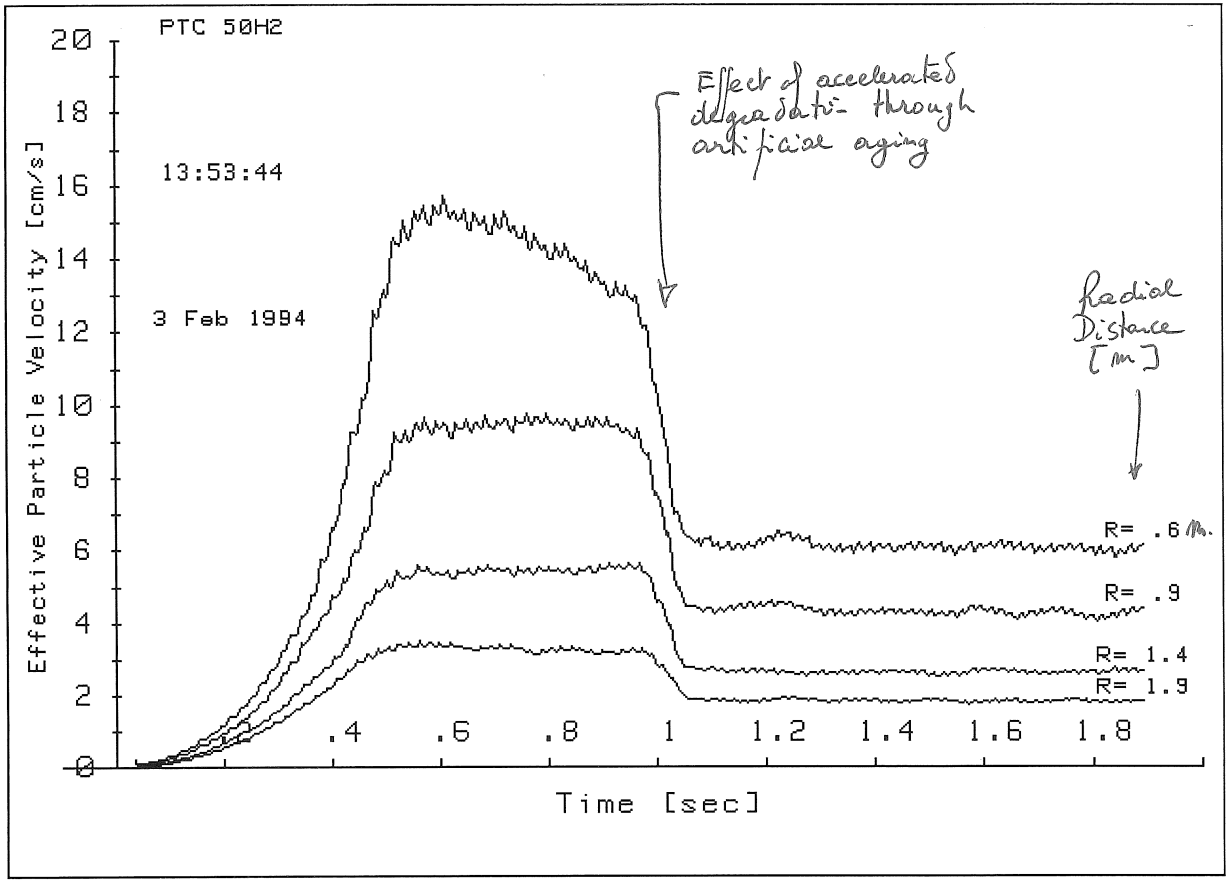


Sheet Pile behavior (over Tcal [= 2 sec.])



Sleet file behavior Details

(last 100 ms before Tcoe)



VIBRATION LEVELS (RMS)

version 'HYPERVIB2' 3 Feb 1994 14:21:05

0 2 1 2 0 15 15 1

****

BBRI Sample Problem

Hingene March 1993

****

PTC 50H2

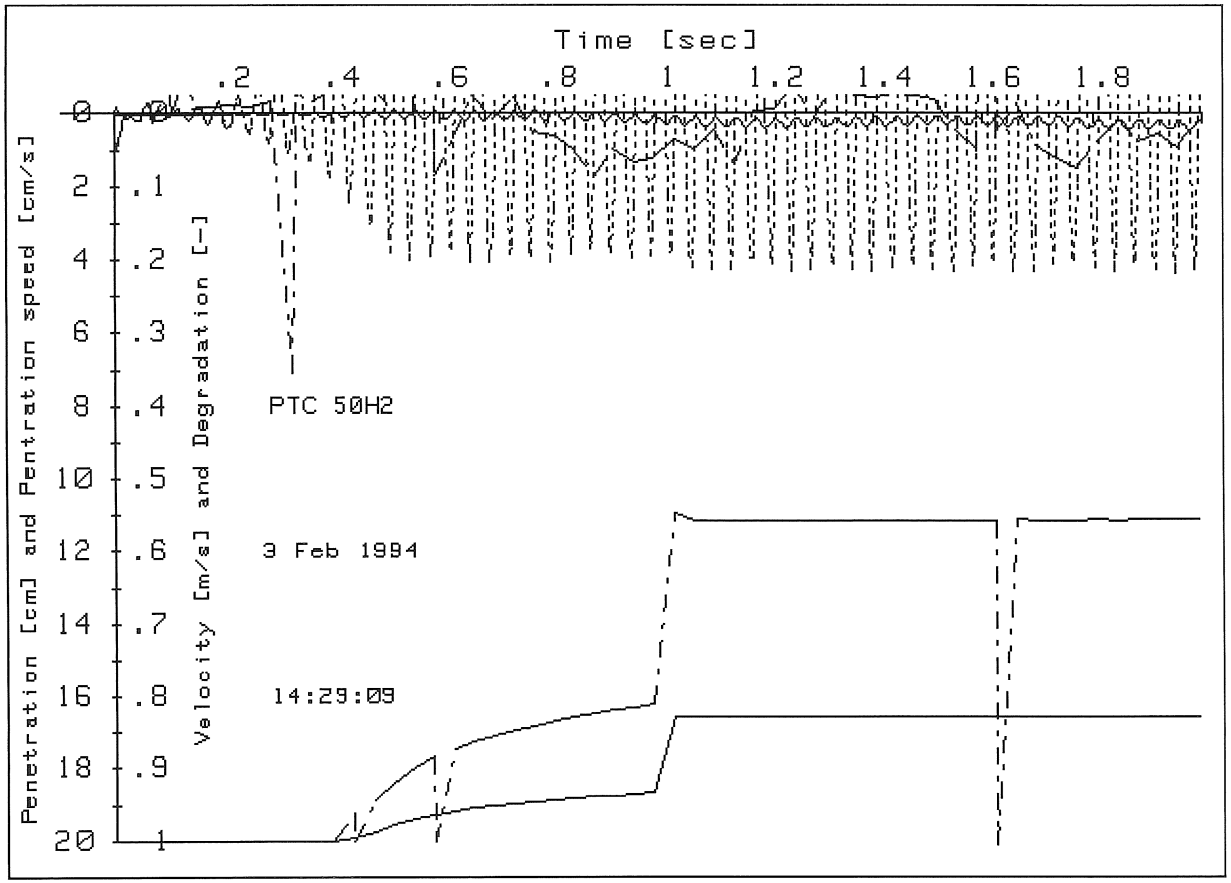
Eccentric Moment = 50 kg.m
Frequency = 27 Hz
Vibrating Mass of Vibrator = 6700 kg
Stationary mass of Vibrator = 3500 kg

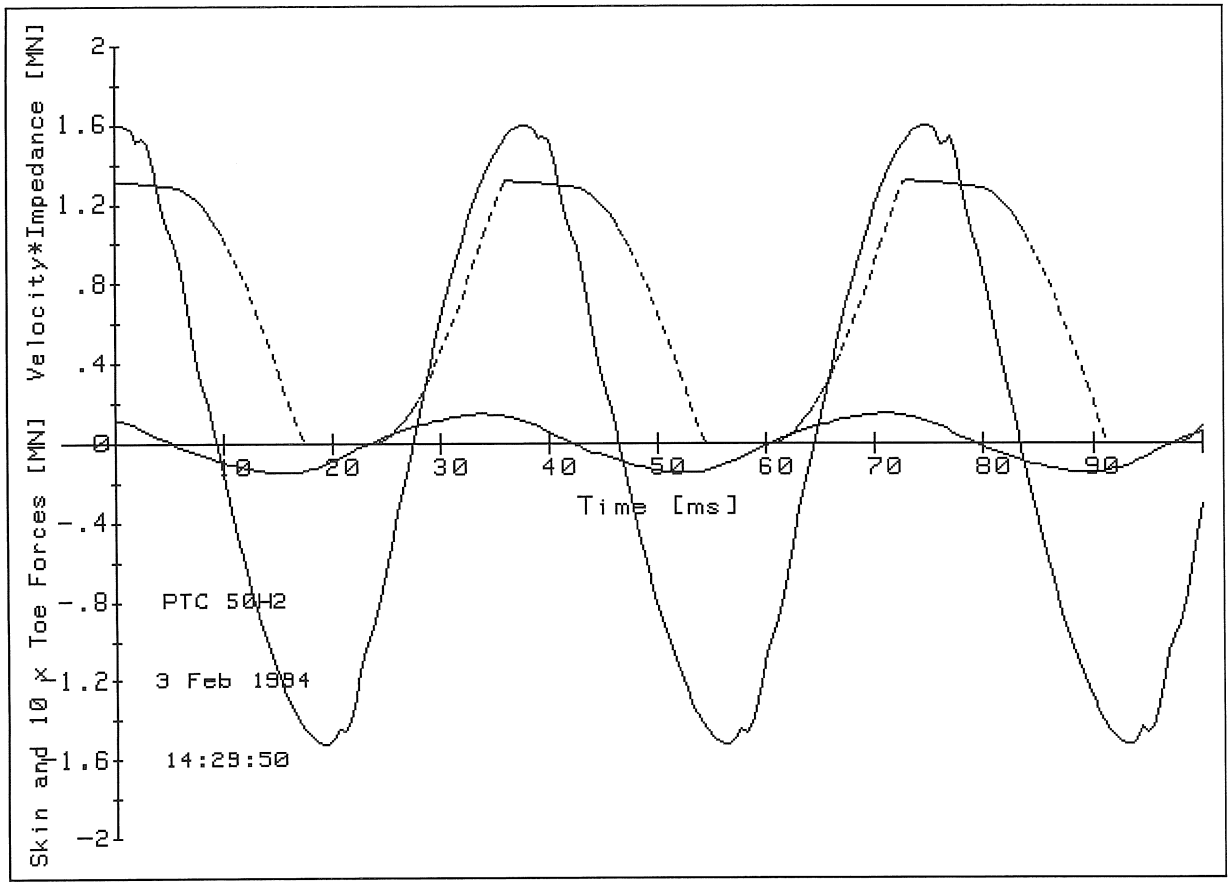
Section of Sheet pile = 167 cm2
Perimeter of Sheet pile = 2.88 m
Length of Sheet pile = 11.7 m

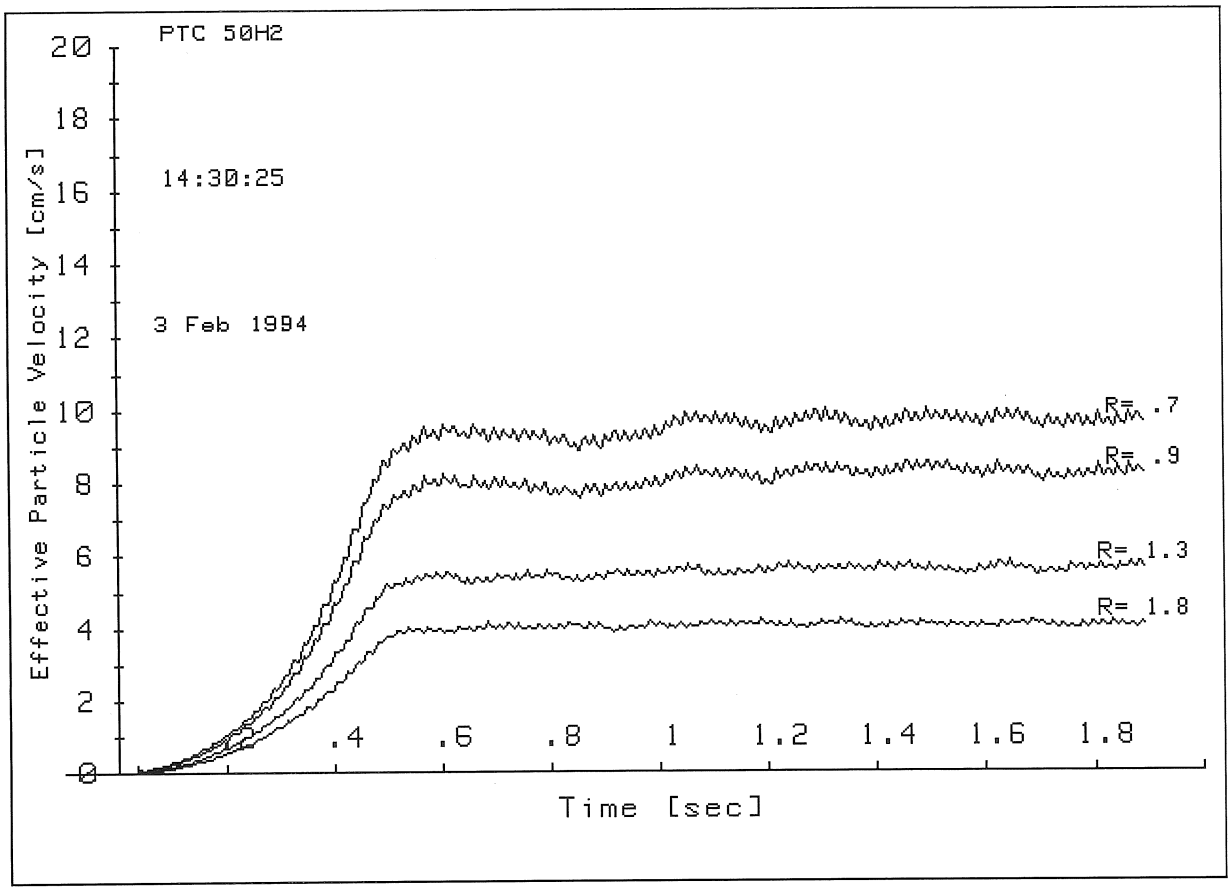
Pile penetration = 10 m
Depth to water table = 8 m
Number of radial increments = 10
FRICTION: Average cone resistance = 6000 kPa
Friction Ratio = 3 %
TOE : Cone resistance = 10000 kPa
Friction Ratio = 2 %
delta= .0005
ntmax= 4000

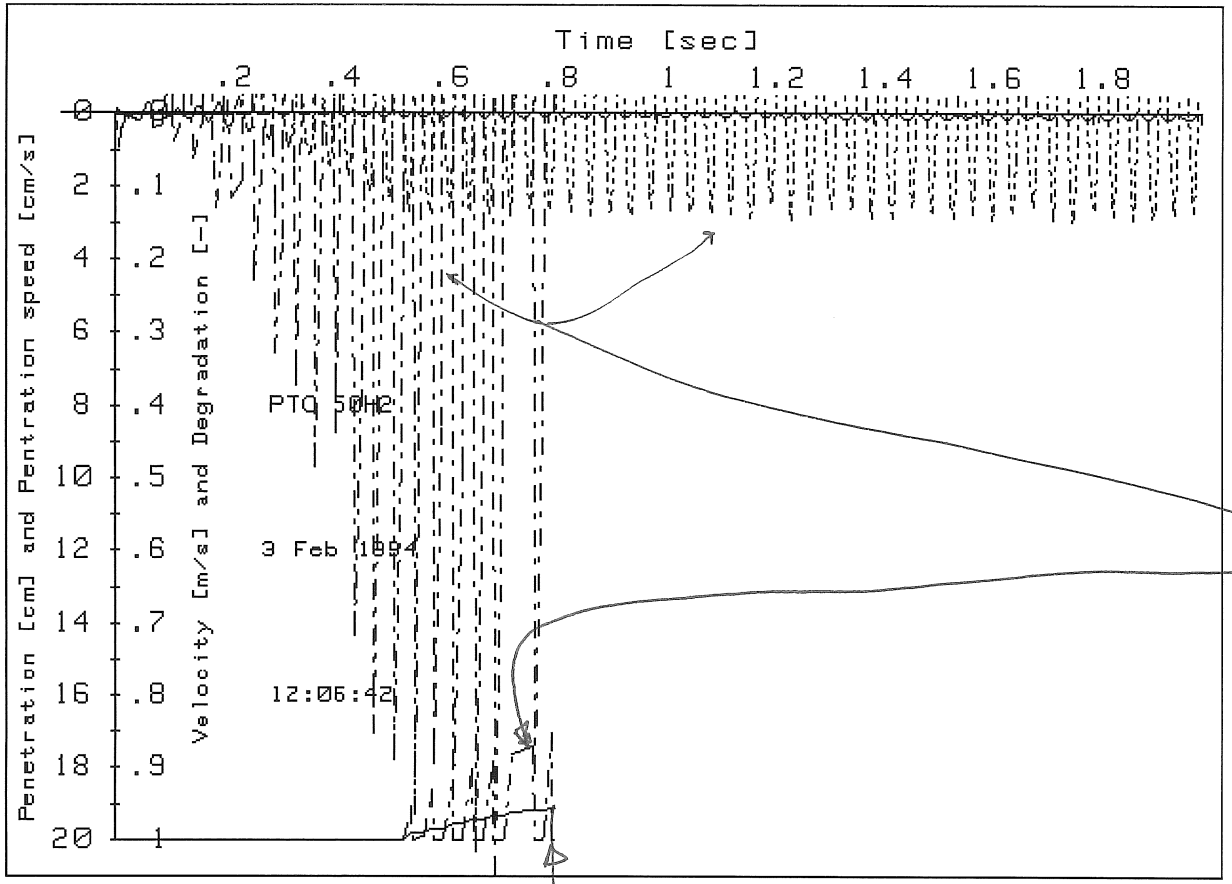
ESTIMATED RESULTS

Estimated driving speed at 10 m. is .51 m/min at early regime
Estimated driving speed at 10 m. is .13 m/min at full regime


Time [sec]
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
0
2
4
6
8
10
12
14
16
18
20
Penetration [cm] and Pentration speed [cm/s]
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Velocity [m/s] and Degradation [-]
PTC 50H2
3 Feb 1994
14:29:09


Skin and 10 x Toe Forces [MN] Velocity*Impedance [MN]
2
1.6
1.2
.8
.4
0
-.4
-.8
-1.2
-1.6
-2
10
20
30
40
50
60
70
80
90
Time [ms]
PTC 50H2
3 Feb 1984
14:29:50


PTC 50H2
14:30:25
3 Feb 1994
Effective Particle Velocity [cm/s]
20
18
16
14
12
10
8
6
4
2
0
.4
.6
.8
1
1.2
1.4
1.6
1.8
Time [sec]
R= .7
R= .9
R= 1.3
R= 1.8



(BAD EXAMPLE), evidenced by

- erratic velocity pattern.
- erratic liquefaction index
- limited time extent of lower functions

```
10   !  PROGRAM "HYPERVIB2"   04 FEBRUARY 1994
20   !  WRITTEN BY DR. ALAIN E. HOLEYMAN
30   !  FOR BELGIAN BUILDING RESEARCH INSTITUTE
40   !INPUT MODULE
50   COM /Ind/ Titre$[20],Stitre$[30],Sstitle$[10]
60   COM /Soil/ Qcf,Frf,Qcb,Frb
70   COM /Vib/ Me,F,Mv,Ms,Areac,Perim,Zlong,Zd,Zw,Nr
80   COM /Parm/ Su(99),Sam(99),Tau(99),Taud(99),Taupos(99),Tauneg(99),Taust(99),
90   COM /Calc/ D(99),Dd(99),V(99),Gamp(99)
100  COM /Plot/ Umaxg(500),Uprog(200),Degg(200),Uliq(200),Fg(250),Vg(250),Fbg(25
110  INTEGER Nipout(5),Nvib(5,200),Nc(99),Nreg(99)
120  !  Program adjustable Parameters
130  Tramp=.5
140  Treg=60
150  Tmreg=1
160  Tcal=2
170  Nplot=500
180  Npld=200
190  Tmaxpl=Tcal
200     Jptlmax=500
210     Jptlmam=200
220     Tdpl=.1
230  Rmax=2
240  Ksi=.02
250  Alph=.03
260  Rho=1.8
270  Mglu=0
280  Ka=15
290  Kab=15
300  Cbc=1
310  Nu=.4
320  Nvel=.2
330  Wop=1.
340  Ncrit=1
350  !
360  !   INPUT
370  !
380      CLEAR SCREEN
390      INPUT "TITLE (20 car max)",Titre$
400      INPUT "SUB-TITLE (30 car max)",Stitre$
410      PRINTER IS 26
420      PRINT "version  'HYPERVIB2'";
430      PRINT TAB(55);DATE$(TIMEDATE);"      ";TIME$(TIMEDATE)
440      PRINT Tr,Tcal,Ncrit,Rmax,Mglu,Ka,Kab,Cbc
450      PRINT "";
460      PRINT "****************************************"
470      PRINT TAB(10);Titre$
480      PRINT TAB(5);Stitre$
```

```
490       PRINT "****************************************"
500       PRINT ""
510       PRINTER IS 1
520       PRINT
530       PRINT
540    !
550    !
560    !
570    ! OPERATIONAL PARAMETERS
580       PRINT "Operational Parameters"
590       PRINT
600       PRINT "select key"
610       OFF KEY
620       ON KEY 5 LABEL "INPUT" GOTO 700
630       ON KEY 4 LABEL "CONTINUE" GOTO 1010
640       ON KEY 7 LABEL "DISPLAY" GOTO 870
650       GOTO 650
660    !
670    !
680    !
690    !
700       INPUT "Sub-sub Title, 10 car.",Sstitle$
710       INPUT "Eccentric Moment, [kg.m]",Me
720       INPUT "Frequency, [Hz]",F
730       INPUT "Vibrating Mass of Vibrator, including Clamp, [kg]",Mv
740       INPUT "Stationary mass of Vibrator, [kg]",Ms
750       INPUT "Section of Sheet pile, [cm2]",Areac
760       INPUT "Perimeter of Sheet pile, [m]",Perim
770       INPUT "Length of Sheet pile, [m]",Zlong
780       INPUT "Pile penetration [m] (>0)",Zd
790       INPUT "Depth to water table [m]",Zw
800       INPUT "Number of radial increments (Max 90)",Nr
810       INPUT "Average cone resistance [kPa], Friction Ratio[%] for friction es
820       INPUT "Cone resistance [kPa], Friction Ratio[%] at pile toe",Qcb,Frb
830       GOTO 570
840    !
850    !
860    !
870       PRINT "Sub-sub Title, 10 car.",Sstitle$
880       PRINT "Eccentric Moment, [kg.m]",Me
890       PRINT "Frequency, [Hz]",F
900       PRINT "Vibrating Mass of Vibrator, including Clamp, [kg]",Mv
910       PRINT "Stationary mass of Vibrator, [kg]",Ms
920       PRINT "Section of Sheet pile, [cm2]",Areac
930       PRINT "Perimeter of Sheet pile, [m]",Perim
940       PRINT "Length of Sheet pile, [m]",Zlong
950       PRINT "Pile penetration [m] (>0)",Zd
960       PRINT "Depth to water table [m]",Zw
```

```
970       PRINT "Number of radial increments (Max 90)",Nr
980       PRINT "Average cone resistance [kPa], Friction Ratio[%] for friction es
990       PRINT "Cone resistance [kPa], Friction Ratio[%] at pile toe",Qcb,Frb
1000      GOTO 570
1010    !
1020      CLEAR SCREEN
1030      OFF KEY
1040      PRINT "CALCULATION IN PROGRESS..."
1050      PRINTER IS 26
1060      PRINT
1070      PRINT Sstitle$
1080      PRINT
1090      PRINT "Eccentric Moment = ",Me,"kg.m"
1100      PRINT "Frequency = ",F,"Hz"
1110      PRINT "Vibrating Mass of Vibrator = ",Mv,"kg"
1120      PRINT "Stationary mass of Vibrator = ",Ms,"kg"
1130      PRINT
1140      PRINT "Section of Sheet pile = ",Areac,"cm2"
1150      PRINT "Perimeter of Sheet pile = ",Perim,"m"
1160      PRINT "Length of Sheet pile = ",Zlong,"m"
1170      PRINT
1180       PRINT "Pile penetration =",Zd,"m"
1190       PRINT "Depth to water table =",Zw,"m"
1200       PRINT "Number of radial increments =",Nr
1210       PRINT "FRICTION: Average cone resistance =",Qcf,"kPa"
1220       PRINT "                  Friction Ratio  =",Frf,"%"
1230       PRINT "TOE :             Cone resistance =",Qcb,"kPa"
1240       PRINT "                  Friction Ratio  =",Frb,"%"
1250    !
1260    !  Calculation of mechanical coefficients
1270    !
1280      Aream=Areac/10000
1290      Gams=7.85
1300      Mpm=Aream*Zlong*Gams
1310      Mvm=Mv/1000
1320      Msm=Ms/1000
1330      Mem=Me/1000
1340      M=Mpm+Mvm
1350      Om=2*PI*F
1360      Fv=Mem*Om*Om
1370      G=9.81
1380      We=(M+Msm)*G
1390      Wef=Wop*We
1400      Ago=Fv/M/G
1410      Mu=(Msm+M)/M
1420      Cmat=5200
1430      Imped=Gams*Cmat*Aream
1440    Nipout(0)=0
```

```
1450  Nipout(1)=2
1460  Nipout(2)=INT(Nr/3)
1470  Nipout(3)=INT(2*Nr/3)
1480  Nipout(4)=Nr-1
1490  !
1500  !  Calculation of soil coefficients
1510  !
1520  !
1530  Gmax=Ka*Qcf
1540  X=1.5*(Frf-2)
1550  Smax=(.65+.35*(EXP(X)-EXP(-X))/(EXP(X)+EXP(-X)))*Qcf*Frf/100
1560  Rp=Perim/2/PI
1570  Dr=(Rmax-Rp)/Nr
1580  Dz=Alph*Dr
1590  R=Rp-Dr/2
1600  Zp=Zd-Dz/2
1610  Sam(0)=M+Mglu
1620    FOR I=1 TO Nr
1630  R=R+Dr
1640  Zp=Zp+Dz
1650  Sum=2*PI*R*Zp
1660  Sam(I)=Rho*Sum*Dr
1670  Su(I-1)=Sum*(1-Dr/2/R)
1680     NEXT I
1690  Bkr=2.5*Gmax*Zd
1700  Cf=2*PI*Rmax*(Zp+Dz/2)*SQR(Gmax*Rho)
1710  Jvel=.1*Frf
1720  Tanp=EXP(Frf-3.5)
1730  Tanm=EXP(3.5-Frf)
1740  Plid=50*(1+(Tanp-Tanm)/(Tanp+Tanm))
1750  Gamtu=Smax/2/Gmax
1760  Ptu=Plid/2+25
1770  Zliq=MAX(0.,Zd-Zw)
1780  Znliq=Zd-Zliq
1790  Gb=Kab*Qcb
1800  Areb=Aream
1810  Fbmax=Areb*Qcb/1.3
1820  Rb2=Areb/PI
1830  Rb1=SQRT(Rb2)
1840  Bkb=4*Gb*Rb1/(1-Nu)
1850  Cb=Cbc*1.8*Areb*SQRT(Rho*Gb)
1860  Qakep=Fbmax/Bkb
1870     !
1880     !  Calculation of movements
1890     !
1900     Ttot=0
1910     Dtcrit=Dr/SQR(Gmax/Rho)
1920     Deltat=Dtcrit/Ncrit
```

```
1930     Deltat=1/Deltat
1940     Alo5=LGT(5)
1950     Alo2=LGT(2)
1960     Alodel=LGT(Deltat)
1970     Npuis=INT(Alodel)
1980     Amant=Alodel-Npuis
1990     Mult=10
2000     IF Amant<=Alo5 THEN Mult=5
2010     IF Amant<=Alo2 THEN Mult=2
2020     IF Amant=0 THEN Mult=1
2030     Mdiv=10^Npuis
2040     Ndelta=Mult*Mdiv
2050     Delta=1/Ndelta
2060     Tpl=Tmaxpl/Nplot
2070     IF Tpl<Delta THEN Delta=Tpl
2080     Npl=INT(Tpl/Delta)
2090     !
2100     Tcalc=MIN(Tcal,2)
2110     Tav=Tcalc/F
2120     Npav=INT(Tav/Tpl)
2130     !
2140     Tpld=Tdpl/Npld
2150     IF Tpld<Delta THEN Delta=Tpld
2160     Npdl=INT(Tpld/Delta)
2170     Ntmax=Tmaxpl/Delta
2180     PRINT "delta=",Delta
2190     PRINT "ntmax=",Ntmax
2200   !
2210   !   Initialization
2220   !
2230    FOR I=0 TO Nr
2240   D(I)=0
2250   Dd(I)=0
2260   V(I)=0
2270   Tau(I)=0
2280   Taud(I)=0
2290   Taust(I)=0
2300   Tauend(I)=Smax
2310   Taupos(I)=0
2320   Tauneg(I)=0
2330   Nc(I)=0
2340   Degr(I)=1
2350   Nreg(I)=0
2360   Gamp(I)=Gamtu
2370    NEXT I
2380   T=0
2390   Ntincr=0
2400   Io=0
```

```
2410    Im=0
2420    Ipl=0
2430    Jptl=0
2440    Jptlm=0
2450    Fb=0
2460    Fbt=0
2470    Ipld=0
2480    PRINTER IS 1
2490     !
2500     ! Time incrementataion
2510     !
2520     Ntincr=Ntincr+1
2530     T=Ntincr*Delta
2540     Ipl=Ipl+1
2550     IF Ipl<Npl THEN GOTO 2640
2560     Jptl=Jptl+1
2570     PRINT ".";
2580     Ipl=0
2590     FOR Ipout=0 TO 4
2600     Nip=Nipout(Ipout)
2610     Vib(Ipout,Jptl)=V(Nip)
2620     NEXT Ipout
2630     Umaxg(Jptl)=D(0)
2640     IF T<Tmaxpl-Tdpl THEN GOTO 2740
2650     IF T>Tmaxpl THEN GOTO 2740
2660     Ipld=Ipld+1
2670     IF Ipld<Npdl THEN GOTO 2740
2680     Jptld=Jptld+1
2690     Ipld=0
2700     Vg(Jptld)=V(0)
2710     Fg(Jptld)=Taud(0)*Su(0)
2720     Fbg(Jptld)=Fbt
2730     !
2740     Omt=MIN(Om,Om*T/Tramp)
2750     Fvt=Mem*Omt*Omt*SIN(Om*T)
2760        FOR I=0 TO Nr
2770        Dd(I)=V(I)*Delta
2780        D(I)=D(I)+Dd(I)
2790        NEXT I
2800        !
2810        FOR I=0 TO Nr-1
2820        Ti=Tau(I)
2830        Tp=Taupos(I)
2840        Tn=Tauneg(I)
2850        Dgam=(Dd(I)-Dd(I+1))/Dr
2860        Gam=(D(I)-D(I+1))/Dr
2870        IF Dgam>=0 AND Ti=Tp THEN GOTO 3260
2880        IF Dgam<=0 AND Ti=Tn THEN GOTO 3260
```

```
2890        ! change of course !
2900        IF Dgam<=0 THEN GOTO 3210
2910        Nc(I)=Nc(I)+1
2920        ! reload
2930        Taust(I)=Ti
2940        Gamrep=(Gamp(I)-Gam)/2
2950        IF Gamrep<=Gamtu THEN GOTO 3030
2960        Tu=SQRT(-1+Gamrep/Gamtu)/Ptu
2970        Neq=(Degr(I))^(-1/Tu)
2980        IF T<Tcal-Tmreg THEN GOTO 3020
2990        IF Nreg(I)>0 THEN GOTO 3020
3000        Neq=Neq+Treg*F
3010        Nreg(I)=Nreg(I)+1
3020        Degr(I)=(Neq+1)^(-Tu)
3030        Snew=Smax*(Degr(I)*Zliq+Znliq)/Zd
3040        Tauend(I)=Snew
3050        Taupos(I)=Ti
3060        IF I>0 THEN GOTO 3200
3070        PRINT "Time =",T,"sec"
3080        IF Jptlm>=Jptlmam THEN GOTO 3200
3090        Nvib(0,Jptlm)=Ntincr
3100        Degg(Jptlm)=Degr(0)
3110        Gamdr=Gamrep/Gamtu/2
3120        Wtot=Gamdr-LOG(1+Gamdr)
3130        Wel=Gamdr*Gamdr/(Gamdr+1)/2
3140        Relos=(Wtot-Wel)/Wel
3150        Kapla=2*Neq*EXP(5*Gamrep)
3160        Reliq=Relos/4*LOG(1+Kapla)
3170        Uliq(Jptlm)=MIN(1.,Reliq)
3180        Uprog(Jptlm)=D(0)
3190        Jptlm=Jptlm+1
3200        GOTO 3260
3210        ! unload
3220        Taust(I)=Ti
3230        Gamp(I)=Gam
3240        Tauend(I)=-Smax*(Degr(I)*Zliq+Znliq)/Zd
3250        Tauneg(I)=Ti
3260        Tr=Tauend(I)-Taust(I)
3270        Eta=(Ti-Taust(I))/Tr
3280        Stif=Gmax*Degr(I)*(1-Eta)*(1-Eta)
3290        Dtau=Dgam*Stif
3300        Ti=Ti+Dtau
3310        Tau(I)=Ti
3320        IF Ti>Taupos(I) THEN Taupos(I)=Ti
3330        IF Ti<Tauneg(I) THEN Tauneg(I)=Ti
3340        Vabs=ABS(V(I)-V(I+1))
3350        Taud(I)=Ti*(1+Jvel*Vabs^Nvel)/1.4573
3360        NEXT I
```

```
3370      ! forces calculations
3380      Dub=Dd(0)
3390      Ub=D(0)
3400      Fb=Fb+Dub*Bkb
3410      IF Fb>Fbmax THEN Fb=Fbmax
3420      IF Fb<0 THEN Fb=0
3430      Vb=V(0)
3440      Fbt=Fb+Cb*Vb
3450      IF Fbt<0 THEN Fbt=0
3460      !
3470      V(0)=V(0)+(Fvt+Wef-Taud(0)*Su(0)-Fbt)/Sam(0)*Delta
3480      V(Nr)=V(Nr)+(Taud(Nr-1)*Su(Nr-1)-Cf*V(Nr)-Bkr*D(Nr))/Sam(Nr)*Delta
3490      FOR I=1 TO Nr-1
3500      V(I)=V(I)+(Taud(I-1)*Su(I-1)-Taud(I)*Su(I))/Sam(I)*Delta
3510      NEXT I
3520       IF T>Tcal THEN GOTO 3540
3530       GOTO 2520
3540     PRINTER IS 26
3550     PRINT
3560     PRINT "ESTIMATED RESULTS"
3570     Ncyclec=INT(Tmreg*F)-2
3580     Vpen=60*2*(Uprog(Jptlm-1)-Uprog(Jptlm-1-Ncyclec))/(Nvib(0,Jptlm-1)-Nvib
3590     Vpen=INT(100*Vpen)/100
3600     PRINT
3610     Ncycler=INT((Tcal-Tramp-Tmreg)*F)-5
3620     Jen=Jptlm-Ncyclec-3
3630     Vpeni=60*2*(Uprog(Jen)-Uprog(Jen-Ncycler))/(Nvib(0,Jen)-Nvib(0,Jen-Ncyc
3640     Vpeni=INT(100*Vpeni)/100
3650     PRINT
3660     PRINT "Estimated driving speed at",Zd;"m. is";Vpeni;"m/min at early reg
3670     PRINT "Estimated driving speed at",Zd;"m. is";Vpen;"m/min at full regim
3680     Fonet=INT(We-Snew*Su(0)-Fbmax)
3690     IF Fonet<0 THEN GOTO 3710
3700     PRINT "CAUTION: Dead weight in excess of resitance by",Fonet,"kN"
3710     !
3720     PRINTER IS 1
3730     CLEAR SCREEN
3740     PRINT "TO PRINT GRAPH, FOLLOW THIS PROCEDURE STEP BY STEP:"
3750     PRINT
3760     PRINT "1. Downsize Alpha Window"
3770     PRINT "2. Downsize Graph Window"
3780     PRINT "3. Click on Alpha Button"
3790     PRINT "4. Maximize Graph Window"
3800     PRINT "5. 'Print Graph' from pull-down Menu"
3810     !
3820     !
3830     !
3840     !  Graphical Output
```

```
3850     !
3860     GRAPHICS ON
3870     !  sheetpile penetration
3880     GINIT
3890     GCLEAR
3900     GESCAPE CRT,30
3910     GESCAPE CRT,35
3920     RECTANGLE 139,108,FILL
3930     PEN 0
3940     DEG
3950     VIEWPORT 0,139,0,108
3960     WINDOW -100,1020,-.21,.03
3970     FRAME
3980     CLIP -50,1000,-.2,0.
3990     AXES 100,.01,0,0,1,50
4000     CLIP -100,1000,-.21,.005
4010     !
4020     Jptl=0
4030     MOVE 0,-Umaxg(0)
4040     FOR Jptl=1 TO Jptlmax
4050     DRAW 2*Jptl,-Umaxg(Jptl)
4060     NEXT Jptl
4070     !
4080     LINE TYPE 4
4090     MOVE 0,Vib(0,0)/5
4100     FOR Jptl=1 TO Jptlmax
4110     DRAW 2*Jptl,Vib(0,Jptl)/5
4120     NEXT Jptl
4130     !
4140     LINE TYPE 7
4150     MOVE 0,0
4160     FOR J=0 TO Jptlm-1
4170     DRAW (Nvib(0,J)/Ntmax)*1000,-2*(Uprog(J+1)-Uprog(J))/(Nvib(0,J+1)-Nvib(
4180     NEXT J
4190     !
4200     LINE TYPE 1
4210     MOVE 0,-.2
4220     FOR J=1 TO Jptlm-1
4230     DRAW Nvib(0,J)*(1000/Ntmax),Degg(J)*-.2
4240     NEXT J
4250     !
4260     LINE TYPE 7
4270     MOVE 0,-.2
4280     FOR J=1 TO Jptlm-1
4290     DRAW Nvib(0,J)*(1000/Ntmax),(Uliq(J)-1)*.2
4300     NEXT J
4310     CLIP -100,1000,-.21,.03
4320     !
```

```
4330     LINE TYPE 1
4340     CSIZE 4
4350     LDIR 0
4360     LORG 4
4370     FOR I=1 TO 10
4380        MOVE 100*I,.005
4390        LABEL I*Tmaxpl/10
4400     NEXT I
4410     LORG 8
4420     FOR I=0 TO 10
4430        MOVE -20,-.02*I
4440        LABEL I*2
4450        MOVE 50,-.02*I
4460        LABEL I/10
4470     NEXT I
4480     LORG 4
4490     MOVE 500,.015
4500     LABEL "Time [sec]"
4510     CSIZE 3
4520     LORG 5
4530     MOVE 200,-.08
4540     LABEL Sstitle$
4550     MOVE 200,-.12
4560     LABEL DATE$(TIMEDATE)
4570     MOVE 200,-.16
4580     LABEL TIME$(TIMEDATE)
4590     LDIR 90
4600     MOVE -80,-.1
4610     LABEL "Penetration [cm] and Pentration speed [cm/s]"
4620     MOVE 80,-.1
4630     LABEL "Velocity [m/s] and Degradation [-]"
4640     PAUSE
4650     DIALOG "INFORMATION","GRAPHICS DUMP"
4660     GCLEAR
4670     !      Sheet pile force and velocity
4680     GESCAPE CRT,30
4690     GESCAPE CRT,35
4700     RECTANGLE 139,108,FILL
4710     PEN 0
4720     DEG
4730     VIEWPORT 0,139,0,108
4740     Fscale=2000
4750     WINDOW -100,1020,-1.1*Fscale,1.1*Fscale
4760     FRAME
4770     CLIP -50,1000,-Fscale,Fscale
4780     AXES 100,Fscale/10,0,0,1,50
4790     CLIP -100,1000,-1.05*Fscale,1.05*Fscale
4800     !
```

```
4810      Jptl=0
4820      MOVE 0,Fg(1)
4830      FOR Jptl=1 TO Npld
4840      DRAW 5*Jptl,Fg(Jptl)
4850      NEXT Jptl
4860      !
4870      LINE TYPE 4
4880      MOVE 0,Fbg(1)*10
4890      FOR Jptl=1 TO Npld
4900      DRAW 5*Jptl,Fbg(Jptl)*10
4910      NEXT Jptl
4920      !
4930      LINE TYPE 7
4940      MOVE 0,Vg(1)*Imped
4950      FOR Jptl=1 TO Npld
4960      DRAW 5*Jptl,Vg(Jptl)*Imped
4970      NEXT Jptl
4980      !
4990      LINE TYPE 1
5000      CLIP -100,1000,-1.1*Fscale,1.1*Fscale
5010      CSIZE 3.5
5020      LDIR 0
5030      LORG 4
5040      FOR I=1 TO 9
5050         MOVE 100*I,-Fscale/10
5060         LABEL I*Tdpl*100
5070      NEXT I
5080      LORG 8
5090      FOR I=-5 TO 5
5100         MOVE -5,Fscale/5*I
5110         LABEL I*Fscale/5000
5120      NEXT I
5130      LORG 4
5140      MOVE 500,-Fscale/5
5150      LABEL "Time [ms]"
5160      CSIZE 3
5170      LORG 5
5180      MOVE 100,-.4*Fscale
5190      LABEL Sstitle$
5200      MOVE 100,-.6*Fscale
5210      LABEL DATE$(TIMEDATE)
5220      MOVE 100,-.8*Fscale
5230      LABEL TIME$(TIMEDATE)
5240      LDIR 90
5250      LORG 4
5260      MOVE -60,0
5270      LABEL "Skin and 10 x Toe Forces [MN]  Velocity*Impedance [MN]"
5280      PAUSE
```

```
5290     !
5300     !  Vibration Levels
5310     !
5320     GCLEAR
5330     GESCAPE CRT,30
5340     GESCAPE CRT,35
5350     RECTANGLE 139,108,FILL
5360     PEN 0
5370     DEG
5380     VIEWPORT 0,139,0,108
5390     WINDOW -100,1020,-.03,.21
5400     FRAME
5410     CLIP -50,1000,-0.,.2
5420     AXES 100,.01,0,0,1,50
5430     CLIP -100,1000,-.005,.21
5440     !
5450     CSIZE 3
5460     FOR Ipout=1 TO 4
5470     Vim=0
5480     FOR J=1 TO Npav
5490     Vim=Vim+Vib(Ipout,J)*Vib(Ipout,J)
5500     NEXT J
5510     MOVE Npav,SQRT(Vim/Npav)
5520     FOR J=Npav TO Jptlmax-Npav
5530     Vim=Vim+Vib(Ipout,J+1)*Vib(Ipout,J+1)-Vib(Ipout,J-Npav+1)*Vib(Ipout,J-N
5540     DRAW 2*J-Npav,SQRT(Vim/Npav)
5550     NEXT J
5560     LORG 4
5570     IMOVE 0,0
5580     Nip=Nipout(Ipout)
5590     Ripout=Rp+Nip*Dr
5600     Ripout=(INT(Ripout*10))/10
5610     LABEL "R=";Ripout
5620     NEXT Ipout
5630     !
5640     LINE TYPE 1
5650     CLIP -100,1000,-.03,.21
5660     CSIZE 4
5670     LDIR 0
5680     LORG 4
5690     FOR I=1 TO 10
5700        MOVE 100*I,.005
5710        LABEL I*Tmaxpl/10
5720     NEXT I
5730     LORG 8
5740     FOR I=0 TO 10
5750        MOVE -20,.02*I
5760        LABEL I*2
```

```
5770      NEXT I
5780      LORG 4
5790      MOVE 500,-.015
5800      LABEL "Time [sec]"
5810      CSIZE 3
5820      MOVE 100,.12
5830      LABEL DATE$(TIMEDATE)
5840      MOVE 100,.16
5850      LABEL TIME$(TIMEDATE)
5860      MOVE 100,.2
5870      LABEL Sstitle$
5880      LDIR 90
5890      MOVE -60,.1
5900      LABEL "Effective Particle Velocity [cm/s]"
5910      PAUSE
5920      END
```